LBNL TECHNICAL IMPLEMENTING PROCEDURE ELM-2.0, Rev 0

Gravity Methods

1.0 PURPOSE.

1.1 To assure the accuracy, validity, and applicability of the methods used at the Nevada Test Site or other designated areas as part of the geophysical investigations necessary to evaluate terrain under consideration for the disposal of high-level radioactive waste, this procedure is a guide for Lawrence Berkeley National Laboratory (LBNL) personnel and contractors performing the described activity.

1.2 This procedure describes the components of the work, the principles of the methods used, and their limits. It also describes the detailed methods to be used for calibration, operation, and performance verification of any equipment, if needed. In addition, it defines the requirements for data acceptance, documentation, and control; and it provides a means of data traceability.

2.0 SCOPE.

2.1 This procedure applies to all YMP-LBNL personnel and their contractors who may perform work referred to in Para. 1.1, or use data obtained from this procedure.

2.2 For all technical activities, data collected from using this procedure and any equipment calibrations or recalibrations that may be required shall be in accordance with this technical procedure. Variations are allowed only if and when this procedure is formally revised, or otherwise modified, as described in Para. 8.

3.0 PROCEDURES.

Gravity methods shall be used to help interpret the subsurface geologic structure and framework of southern Nevada, as part of a cooperative effort to help geophysically characterize potential radioactive waste storage sites.

3.1 Objective: Gravity surveys are employed to help locate and identify the cause of gravity anomalies in the Earth's gravity field. Gravity anomalies may be related to near-surface geology or to geologic structural features within the Earth's crust. Gravity data may reveal the existence of faults and their subsurface configuration, the distribution of stratigraphic units, intrusive bodies, calderas, and the thickness and shape of sedimentary basins.

3.2 Methods Used: Gravity data collection, reduction, and interpretation shall be based on general methods and principles such as, but not limited to, those described by Hayford and Bowie (1912), Hammer (1939), Heiland (1940), Swick (1942), Jakosky (1957), Heiskanen and Vening Meinesz (1958), Talwani and Landisman (1959), Talwani and Ewing (1960), Grant and West (1965), Robbins and Oliver (1970), Plouff (1975, 1977), Dobrin (1988), Nettleton (1976), Sharma (1976), and Telford and others (1976).

3.2.1 GRAVITY DATA COLLECTION AND PROCESSING: When anomalies are to be determined, gravity data shall be collected at locations where an elevation is determinable such as, but not limited to, photogrametric spot elevations, bench marks, or surveyed points. Data shall be collected using gravity meters having sensitivities, precisions, and accuracies equal to or exceeding those of LaCoste and Romberg or Worden gravity meters. Collection of high-precision gravity data (Jachens, 1978; Jachens and others, 1983) shall follow a high-precision measurement technique as exemplified in Attachment 1. Operation of gravity meters shall be in accord with the instruction manuals supplied by the gravity meter manufacturer.

Gravity stations shall be tied to the same base station at the beginning and end of each day or more often (closed loop) when accuracies greater than about 0.2 mGal are desired. High-precision gravity stations shall be occupied at least twice with at least 3 gravity meters.

Raw gravity data are merged with location data and gravity corrections and anomalies are determined. Standard gravity reduction methods shall be used on all gravity data and are based on, but not limited to, the general methods and principles described in references listed in Para 3.2.

3.2.2 GRAVITY INTERPRETATION: Gravity interpretations shall be based on general methods and principles such as, but not limited to, those described in references listed in Para 3.2.

3.2.3 SURVEYING METHODS: Surveying methods used to establish vertical and horizontal locations of gravity data shall be in accord with general surveying methods and principles such as, but not limited to, those described by Davis and Kelly (1969).

3.2.4 SAMPLE COLLECTION: Samples are usually collected from, but not limited to, rock outcrops or drill-cores. There are no special requirements for sample collection nor do samples require special treatment prior to or after making density measurements. However, collection of a representative sample is desirable for determining the overall or average density of a particular rock type.

3.2.5 DENSITY MEASUREMENTS: Density measurements shall be determined using standard techniques such as, but not limited to, the buoyancy method (Carmichael, 1984). If applicable, weight measurements shall be made using a balance such as, but not limited to, a Sartorius electronic balance.

3.3 Materials/Equipment Required: (No special handling, storage and/or shipping is required unless otherwise noted.) All materials and equipment shall be as per listed manufacturer or equivalent.

3.3.1 GRAVITY METER: Gravity meter such as, but not limited to, a LaCoste and Romberg Model G gravity meter. LaCoste and Romberg G meters have an operating range of over 7,000 mGal, a reading accuracy of 0.01 mGal, and a drift rate of less than 1 mGal per month. In addition, LaCoste and Romberg gravity meters are sealed to eliminate effects from changes in atmospheric pressure, are internally pressure compensated, thermostatically controlled, and the sensor is demagnetized and enclosed in a magnetic shield.

3.3.2 SURVEYING INSTRUMENTS: Surveying instrument such as, but not limited to, a Hewlett-Packard 3820A Electronic Total Station. The 3820A is capable of measuring distances up to 1.6 km with a resolution of 1 mm. The 3820A has a 5 km range and a slope distance accuracy of 5 mm + 5 mm/km at an operating temperature of -10 to 40 C and 10 mm + 10 mm/km at operating temperatures of -20 to -10C and 40 to 55 C. The 3820A has a vertical angle accuracy of 2 s (4 s with telescope in reversed position) at an operating temperature of -20 to 55 C.

3.3.3 BALANCES: Balance such as, but not limited to, a Sartorius model 1263. The 1264 has an operating weighing range of 3,000 g, a readability of 0.01 g, and an accuracy of 0.01 g from 0 to 800 g and 0.02 g from 800 to 3,000 g. When the balance exceeds these accuracies then the balance shall be adjusted by a qualified technician or user who has followed the adjustment procedures provided by the manufacturer.

3.3.3.1 STANDARD SAMPLES: Standard samples such as, but not limited to, a set of weights that can be used to check balances prior to an after making a set of measurements.

3.4 Assumptions Affecting the Procedure: The assumptions affecting this procedure are tied to the limitations; see Para. 3.6 for further explanation.

3.5 Data Information: (All software developed for or applied to this procedure shall be in compliance with the requirements of YMP-LBNL-QIP SI.0, General Software Quality Assurance.)

- o All gravity data shall be logged on, but not limited to, data sheets or notebooks and shall include a minimum of meter number, observer, date, time zone used (such as PST, PDT or hours from U.T.), station name, time of reading, and meter reading.
- o Survey data shall be logged on, but not limited to, data sheets or notebooks.
- o Manual terrain corrections shall be logged on, but not limited to, datasheets or notebooks.
- o Collection of samples shall be documented by, but not limited to, data sheets, field notebooks, maps, or air photos.
- o Density measurements shall be logged on, but not limited to, data sheets or notebooks.

3.5.1 QUANTITATIVE/QUALITATIVE CRITERIA: Gravity data shall usually be collected with an instrument accurate to, but not limited to, about 0.05 mGal. The Principal Investigator or designee shall be responsible for validity and applicability of gravity data to geophysical interpretations. Qualitative criteria for acceptance of data include, but are not limited to, the correlation of gravity anomalies to geology or known structural features and other geophysical data.

3.6 Limitations: Interpretation of gravity data are affected by the nonuniqueness property of potential fields, an infinite number of density distributions can yield the same anomaly. Thus, there is a need to constrain the gravity data interpretation with all available geological and geophysical data.

3.7 Calibration Requirements**.** Calibration is required as a part of this technical procedure. All instruments and/or instrument systems shall be calibrated in compliance with the YMP-LBNL-QIP 12.0, Documenting the usage of measuring and test equipment.

3.7.1 Calibration Responsibility: The PI is responsible for calibrations required by this procedure. Calibration shall be in accordance with procedures described or referenced in Para. 3.7.2. Maintenance of all calibration records described in Para. 3.7.3 may be done by a contributing investigator under the direct supervision of the PI.

3.7.2 Calibration Procedures: All calibrations, unless otherwise specified, shall be performed according to manufacturer's range and accuracy specifications. The equipment requiring calibration are the gravity meters, surveying instruments, and balances.

3.7.2.1 GRAVITY METER CALIBRATION:

3.7.2.1.1 The calibration factor of each gravity meter shall be checked yearly. Recalibration shall be made if the meter has sustained any unusual movements which make instrument readings suspect or if base ties or meter performance imply problems.

3.7.2.1.2 Calibration of gravity meters shall be made by taking gravity measurements over established loops or ranges such as, but not limited to, those described by Barnes and others (1969) and Ponce and Oliver (1981). Corrections (or calibration factors) to factory determined calibration tables for gravity meters shall be accurate to about 1 part in 10,000 (Ponce and Oliver 1981, p. 5).

3.7.2.2 SURVEYING INSTRUMENT CALIBRATION: Surveying instruments (see Para. 3.3.2) shall be calibrated and traceable to National Institute of Standards and Technology (NIST).

Electronic distance measuring devices shall be calibrated by a YMP approved vendor prior to use, every two years, and after the last YMP data has been collected.

3.7.2.3 STANDARD SAMPLES: Standard samples shall be calibrated once by an approved vendor and again upon conclusion of work under the SCP Activity. No yearly or periodic calibration of standard samples is necessary after the first calibration as maximum precision needed does not exceed 0.01 g from 0 to 800 g and 0.02 g from 800 to 3000 g for the balance. NIST standards have a far greater precision then is ever needed for density (specific gravity) measurements.

3.8 Identification and Control of Samples. Samples will be collected and handled as part of this procedure. Samples shall be collected, identified, controlled, and stored in compliance with YMP-LBNL-QIP SII.0, and applicable YMP Administrative and Sample Management Procedures. When applicable, sample nonconformances shall be documented in accordance with YMP-LBNL-SII.0.

3.8.1 Sample Identification: Rock samples may be collected from any site using any method but are usually collected from rock outcrops or drill cores. All outcrop samples shall be identified and labeled in accordance with YMP-LBNL-SII.0, The Collection, Submission, and Documentation of Non-Core and Non-Cutting Samples to the Sample Management Facility for Site Characterization. As part of the data records and documentation, all samples shall include a field sample identifier. The field identifier may correspond to a gravity station location label or may be labeled such as, but not limited to, a 2 digit year, a 2 or 3-digit collector's initials, a sample site, and a sample number (e.g., 84 DAP ym001a).

3.8.2 Control and Storage: Sample control shall be in compliance with YMP-LBNL-QIP-SII.0, Identification and Control of Samples. Traceability of samples shall be maintained through the use of the Sample Management Facility (SMF) barcode identifications (YMP-LBNL-SII.0) which shall be recorded on all appropriate QA records associated with this procedure. If samples are to be shipped, they shall be properly packed and labeled to ensure integrity and traceability. Samples shall reside in the custody of the PI, or delegate, responsible for the implementation of this procedure who shall store them in an office or a rock storage facility. The storage life for samples collected per this procedure is indefinite. Final disposition of individual samples, including transfer to another YMP participant, archival, or disposal shall be documented. Total consumption of a sample during analysis shall also be documented. If it is determined that archiving is warranted, the sample shall be submitted to the SMF in accordance with YMP-LBNL-SII.0 or the PI or delegate shall store them in an office or rock storage facility.

3.8.3 Special Treatment: None.

4.0 RECORDS MANAGEMENT.
Documents and data will be prepared and submitted per YMP-LBNL-QIP 17.0. All of the following records are lifetime.

4.1 Anticipated documents and data generated from implementation of this procedure may include the following: gravity field data, location data, terrain correction data, and density data which shall be recorded on, but not limited to, forms, notebooks, or maps.

4.2 Notebooks, forms, or other organized documentation shall be prepared, as appropriate, by the PI or a contributing investigator to record data from this procedure and shall include any information considered by the originator to be pertinent. When in loose-leaf form, each page shall be numbered consecutively and chronologically. All documents shall be signed (or initialed) and dated by the investigator as entries are made. Any revisions shall be lined out, initialed, and dated. Notations by pencil shall be submitted in legible photocopy form.

4.3 In compliance with YMP-LBNL-QIP 12.0, calibration data will be entered, signed and dated, into a notebook or other organized documentation. Computer software used in calibration exercises shall meet the requirements stipulated in YMP-LBNL-QIP SI.0.

5.0 RESPONSIBILITIES. The Principal Investigator (PI) is responsible for assuring full compliance with this procedure. The PI shall require that all personnel assigned to work under this procedure shall have the necessary qualifications and training to adequately perform the procedure; and they shall have a working knowledge of the YMP-LBNL QA Program. When procedure-specific responsibilities are to be delegated to contributing investigators or other personnel, the details of these responsibilities are as stated in this procedure. Special qualifications and/or training unique to the conduct of this procedure are not required. All ongoing investigations shall be identified, at the location of the scientific investigation, to preclude inadvertent interruption and to ensure compatibility of the investigations.

6.0 ACRONYMS AND DEFINITIONS. None.

7.0 REFERENCES.

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Quality Implementation Procedure: YMP-LBNL-QIP12.0.

Quality Implementation Procedure: YMP-LBNL-QIP17.0.

Quality Implementation Procedure: YMP-LBNL-QIP SI.0.

Quality Implementation Procedure: YMP-LBNL-QIP SII.0.

8.0 ATTACHMENTS.

Attachment 1: Example of a High Precision Gravity Measurement Technique

9.0 REVISION HISTORY.

None

10.0 REVIEW AND APPROVALS.

EFFECTIVE DATE:

Preparer	Date	QA Reviewer	Date
Principal Investigator	Date	YMP-LBNL QA Manager	Date
Technical Reviewer	Date	YMP-LBNL Project Manager	Date